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The views expressed in this paper are those of the authors.
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Abstract

The authors empirically measure Canadian bond market liquidity using a number of indicators proposed in the literature and detail, for the first time, price and trade dynamics in the Government of Canada secondary bond market. They find, consistent with Inoue (1999), that the Canadian brokered interdealer fixed-income market is relatively liquid for its size. Liquidity measures are analyzed relative to each other and across securities, and intraday patterns are identified. The authors' results show that trading activity is positively correlated with price volatility, and that signed order flow is significant in explaining contemporaneous high-frequency price movements. They find evidence that trading activity is positively related to liquidity measures in some markets, which suggests that indicators such as trade frequency and trading volume, despite certain drawbacks, can be seen as useful proxies for liquidity. The authors also document Canadian participants' prevalent use of an order expansion protocol, whereby order size can be negotiated upward once a trade has been initiated; although Boni and Leach (2002) identify this practice as consistent with a market where there is relatively strong concern regarding information asymmetry, the authors observe no consistent link between the frequency of its use and observations of trading activity, market liquidity, or price volatility.

JEL classification: G10, G14
Bank classification: Financial markets; Market structure and pricing

Résumé

Les auteurs mesurent empiriquement la liquidité du marché obligataire canadien au moyen d'un certain nombre d'indicateurs proposés dans la littérature et rendent compte, pour la première fois, de la dynamique des prix et des transactions sur le marché secondaire des obligations du gouvernement du Canada. Ils constatent, à l'instar d'Inoue (1999), que le marché canadien des opérations sur titres à revenu fixe conclues par l'entremise de courtiers intermédiaires est relativement liquide pour sa taille. Ils comparent les mesures de la liquidité entre elles et entre les divers titres, et mettent en évidence leurs profils intrajournaliers de variation. Les résultats obtenus indiquent que l'activité du marché est corrélée positivement avec la volatilité des prix et que le flux d'ordres (la somme des transactions effectuées à l'initiative de l'acheteur diminuée des transactions faites à l'initiative du vendeur) permet d'expliquer les mouvements de prix contemporains à fréquence élevée. Les auteurs observent une relation positive entre l'activité et les mesures de la liquidité sur certains marchés, ce qui donne à penser que les indicateurs comme la fréquence et le volume des transactions, malgré certaines lacunes, peuvent être utilisés pour

représenter la liquidité. Ils notent également l'utilisation répandue chez les participants canadiens d'un protocole d'expansion des ordres, en vertu duquel la taille d'un ordre peut être négociée à la hausse une fois la transaction amorcée. Bien que Boni et Leach (2002) estiment cette pratique compatible avec un marché caractérisé par un degré relativement élevé d'asymétrie d'information, les auteurs ne décèlent aucun lien systématique entre sa fréquence d'utilisation et le niveau observé de l'activité, de la liquidité du marché ou de la volatilité des prix.

Classification JEL : G10, G14
Classification de la Banque : Marchés financiers; Structure de marché et fixation des prix

1. Introduction

Studies of market liquidity have tended to focus on conditions in foreign exchange and equity markets. This may be due in part to the availability of high-frequency data in these markets. Recently, several empirical studies of liquidity and intraday price dynamics in the U.S. government securities market have used data from GovPX, a system that reports on activity in the U.S. interdealer broker (IDB) debt market.[1] CanPX, a similar transparency system recently introduced for Canadian debt markets, makes possible an examination of liquidity in the Canadian government securities market. In this preliminary study, we analyze intraday trade and quotation data for 250 trading days over the period from 25 February 2002 to 27 February 2003.

The results reveal a relatively transparent, active, and liquid market, but one where liquidity is variable and concentrated in a small number of benchmark securities. We confirm the findings of other studies that find a link between trading activity and contemporaneous price changes. In comparison with the significantly more liquid U.S. Treasury market, we find that Canadian dealers use strategies more frequently to limit their exposure to the effects of information asymmetry.

Why should we care about liquidity in fixed-income markets? Some research has indicated that market liquidity has a positive, first-order impact on asset returns (e.g., Amihud, Mendelson, and Lauterbach 1997; Datar, Naik, and Radcliffe 1998). Government debt managers are very interested in fostering market liquidity to minimize the cost of public funds, particularly in countries where government borrowing needs are (or have been) declining. Also, market crises are often characterized by a sharp reduction in liquidity. By contributing to a deeper understanding of liquidity, an important objective of this type of research is to help promote high-quality, efficient, and resilient markets.

Although much has been written on liquidity and high-frequency price dynamics in equity markets in particular, there is good reason to believe that the results of these studies may not be entirely applicable to debt markets, because they have significant structural differences (Gravelle 2002). Given the size and importance of fixed-income markets globally, and the recent availability of detailed intraday data, this apparent gap in the finance literature has interested a number of researchers. Wholesale fixed-income markets are also interesting to study, because they typically do not require explicit continuous market presence or have rules that limit the size of bid-ask spreads or price changes; since prices and quotes are allowed to adjust endogenously, these

1. Examples of these studies include Fleming (1997, 2001, and 2002), Fleming and Remolona (1999), Furfine and Remolona (2001), Elton and Green (1998), Boni and Leach (2002), Chordia, Sarkar, and Subrahmanyam (2003), Brandt and Kavajecz (2003), Strebulaev (2002), Green (2003), Cohen and Shin (2003), Fleming and Sarkar (1999), Ng, Leng, and Phuah (2001), and Goldreich, Hanke, and Nath (2002).

markets may be a good proving ground for market microstructure hypotheses. Although studies of conditions in the intraday U.S. Treasury markets have revealed a great deal about those markets, this paper represents the first such examination of the smaller market in Canada.

Since liquidity is an important characteristic of markets, which measures of liquidity are most appropriate? In fixed-income markets, poor data availability has led to a focus on aggregate activity measures, such as trading volume. It is clear, however, that market activity is at best an indirect indicator of trading costs. At worst, activity measures such as trading volume can be misleading, since a high level of market activity is associated not only with liquid and well-functioning markets, but also with episodes of volatility, uncertainty, and turbulence.

Using a new data set, we construct and evaluate a range of activity and liquidity indicators for the Canadian government bond market: bid-ask spreads, trading volume, trade frequency, quote size, trade size, and price-impact coefficients.[2] We propose two new liquidity measures based on participants' use of the limit order expansion protocol, whereby the initial counterparties (and subsequently other dealers) are allowed to negotiate order size upward once a trade at a given price has been initiated.

Our investigation of price-impact coefficients is related to market microstructure research that has explored the link between signed order flow (defined as buyer-initiated trades minus seller-initiated trades) and contemporaneous price changes. In markets where some participants possess private information, this information is incorporated into prices through trading. The greater the information asymmetry, the larger the effect of trading activity on prices (Green 2003). Although we might traditionally think of information asymmetry and the effects of adverse selection on liquidity in the context of opportunistic trading by equity market "insiders," recent studies indicate that orders contain significant price information even in markets where prices are putatively driven by public (macroeconomic) news announcements, such as fixed-income and foreign exchange markets (see Evans and Lyons 2002; Fleming 2001). In particular, dealers' proprietary knowledge of customer order flow and of differences in interpretation regarding public news have been suggested as potential sources of asymmetric information in these markets.

In evaluating the proposed measures, we analyze the correlation coefficients between them, and the price volatility. We observe that while trading volume and trade frequency often exhibit the expected correlation with other measures, they are also positively correlated with price volatility, limiting their potential usefulness.

Quote size and trade size seem to be more appropriate measures, because they are not positively related to price volatility; however, in addition to some conceptual problems, their correlation

2. Price-impact coefficients as suggested by Kyle (1985).

with other measures tends to be weak and/or inconsistent across securities. Only the bid-ask spread and the two estimated price-impact coefficient measures consistently exhibit the expected relationships with each other, and, in almost all cases, with respect to volatility and the other liquidity measures. The bid-ask spread's strong relationship with the more sophisticated price-impact coefficient measures provides some evidence that it is the most appropriate of the intraday indicators evaluated in this paper.

We find that our two measures based on trade-size expansion exhibit no consistent relationships with the other activity and liquidity measures (except for average trade size), nor with price volatility, which suggests that participants' use of this practice cannot be viewed simply as a reaction by risk-averse dealers to relatively volatile and/or illiquid market conditions.

We also explore the question: How liquid is the Canadian IDB market? We find that the Canadian brokered interdealer fixed-income market is relatively liquid for its size, consistent with survey results presented by Inoue (1999); we identify several interesting differences with the much larger (although structurally similar) U.S. Treasury market. In comparing our results with those of Boni and Leach (2002) and Fleming (2001) for the U.S. Treasury market, we observe that Canadian dealers post smaller quotes and make greater use of the order expansion protocol.

2. Measures of Liquidity

Liquidity is an elusive and multi-faceted concept. A popular definition of a liquid market is that participants can rapidly execute large transactions with only a small impact on prices. Market liquidity is usually considered according to at least one of four dimensions: tightness, depth, immediacy, and resiliency. Tightness is the difference between buy and sell prices, or the bid-ask spread. Depth denotes the size of transaction that can be absorbed without affecting prices, or the amount of orders on the order books at a given time. Immediacy is the speed with which orders are filled. Resiliency is the speed or ease with which prices return to "normal" following a temporary order imbalance (CGFS 1999).

These definitions of liquidity are intuitively and theoretically appealing, but only rarely directly observable in markets. Usually, data limitations force us to look at indirect proxies for liquidity that may be less appropriate. This has been especially true for fixed-income markets, which have tended to be decentralized and opaque.

2.1 Trading volume

Trading volume, or the total value of securities traded per unit of time, is an intuitive and widely cited measure of market liquidity. In general, markets that have a relatively large amount of trading activity are considered to be the most liquid, with the lowest per-unit trading costs. This seems to correspond very well with observations regarding the relative liquidity of various markets, such as, for example, benchmark vs. non-benchmark bonds, listed vs. unlisted stocks, or U.S. dollar-euro vs. U.S. dollar-Canadian dollar foreign exchange trading. As an indirect measure of liquidity, however, trading volume is potentially problematic. Theoretical studies have established the positive link between trading volume and liquidity, suggesting that higher trading volume is associated with greater market liquidity. One drawback of trading volume as a liquidity indicator is that it is also associated with price volatility (Andersen 1996; Karpoff 1987), which is thought in turn to be negatively related to market liquidity.

Note also that trading volume, in addition to reflecting market activity with respect to the number of trades experienced, includes effects from any changes in trade size, a measure of liquidity in its own right.

Trading volume has had mixed empirical results as a proxy for market liquidity. Fleming (2001) finds that trading volume is negatively correlated with the bid-ask spread and positively correlated with trade size, which suggests that a higher trading volume is associated with greater liquidity. He also finds, however, that trading volume is negatively correlated with quote size and positively correlated with the price-impact coefficient and the on-the-run/off-the-run yield spread, which implies that a higher trading volume is associated with lower liquidity.

2.2 Trade frequency

Closely related to trading volume, trade frequency, or the number of trades observed per unit of time, is another indirect measure for liquidity. High trading frequency may reflect a more liquid market, but it may also be associated with increased price volatility, which is in turn associated with reduced liquidity. Since it does not include any effects from changes in trade size, however, we might think of trade frequency as a "purer" measure of market activity than trading volume.

Huang, Cai, and Wang (2001) find that trade frequency is more highly correlated with Treasury volatility than is trading volume. Fleming (2001) notes that trading volume has little incremental explanatory power over trade frequency in explaining price changes.

2.3 Bid-ask spread

The bid-ask spread, or the difference between the best bid and offer prices, is a commonly used measure for market liquidity. One-half of the bid-ask spread (i.e., the difference between the price of each quote and the midpoint of the two prices) can be thought of as a directly observable (but not the only) estimate of the cost of execution. In practice, a market that has very low transaction costs is characterized as liquid. In this sense, the bid-ask spread is a relatively direct measure of market liquidity. One limitation of the bid-ask spread is that a spread is good for only a specific set of bid and ask quantities. Where quantities bid and offered vary over time and across securities, observed bid-ask spreads are not truly comparable.

The general absence of rules in institutional over-the-counter (OTC) debt markets regarding minimum tick sizes, maximum bid-ask spreads, or market presence allows the bid-ask spread to adjust more endogenously than in many equity markets. Where there is no specialist with the task of maintaining a smooth, two-sided market for a particular security, participants are free to post or withdraw quotes as they see fit, allowing spreads to fluctuate in response to new information and changes in underlying supply and demand.

In addition to its theoretic and intuitive appeal as a relatively "direct" measure of transaction costs, Fleming (2001) identifies the bid-ask spread as one of the most appropriate liquidity indicators for the U.S. Treasury market due to its high degree of correlation with other (perhaps more sophisticated) measures, such as price impact and benchmark/non-benchmark yield spreads.

2.4 Quote size

Quote size is an appealing proxy for market depth. Often, however, only the inside quotes at the best bid and ask prices are visible, leaving the rest of the order book effectively invisible to observers. Unfortunately, CanPX captures and stores data relating only to the inside quotes. Furthermore, the observed quote size underestimates true market depth where participants may actually be willing to transact more than they explicitly quote; for instance, in markets that allow order size expansion once a trade has been initiated (the "workup," described in section 2.6), such as the Canadian IDBs.

2.5 Trade size

Trade size is another measure of market depth. Although it does not reveal the depth of liquidity faced by market participants ex ante, as an ex post measure of realized depth it may be a more appropriate indicator if participants do not reveal their true trading intentions in their posted

quotes. In our study, trade size reflects the amount that was actually traded at the bid or ask, and includes any negotiations over size that may have taken place once the initial quote was hit or lifted. A comparison of the average trade size and average quote size for a particular security may indicate the relative importance of this practice.

2.6 Participants' use of order expansion (the "workup")[3]

The Canadian brokered interdealer debt markets feature a practice (little-used outside of IDB debt markets) known as the "workup." When a quote is "hit" or "lifted," the workup protocol allows further negotiations over size to take place. At each stage of the negotiation, each participant retains right-of-refusal with respect to further size expansion, and trade size continues to grow until underlying demand on one side or the other has been met. Furthermore, once the trade has been initiated, the associated quote begins to flash on the broker's screen, alerting other participants on the system that a trade is in progress. Once the initial buyer's and/or seller's demand has been satisfied, other dealers are allowed to step in and trade at that price.

One explanation for this practice is that it allows participants to minimize information leakage with respect to their true trading desires. Instead of posting a large quote (which could move the market price against them), the dealer posts a small initial quote, subsequently revealing their true demand only incrementally, and only to the prospective counterparty. The trade size expansion protocol may also serve to limit expected costs with respect to stale quotes: if markets move quickly and a participant suddenly finds their quote on the wrong side of the market price, their obligation to trade is limited. As Boni and Leach (2002) suggest, participants might be expected to make relatively greater use of trade size expansion under relatively illiquid (or otherwise adverse) market conditions, when concerns regarding information leakage and stale quotes may be at their highest.

We propose two liquidity measures based on participants' use of the order expansion protocol: (i) the proportion of total trades that have undergone size expansion, and (ii) the proportion of total trading volume from trades that have undergone size expansion.

2.7 Price-impact coefficients

Kyle (1985) develops a model to address the strategic aspects of informed trading in a market microstructure model. Informed traders in the model can be thought of as information monopolists who act to exploit this advantage. The model is able to characterize how an informed

3. Boni and Leach (2002) provide an excellent description of the right-of-refusal limit order expansion protocol in the interdealer U.S. Treasury market.

trader would choose to transact in order to maximize the value of private information. The price-impact coefficient in the model reflects how much the market adjusts prices to reflect the information content of trades. It measures "the rise (fall) in price that typically occurs with a buyer-initiated (seller-initiated) trade" (Fleming 2001). Kyle's price-impact coefficient can be used to characterize liquidity in financial markets. It is generally felt that liquid markets are those that accommodate trades with the least impact on prices. The intuition is that directional trades will be associated with a larger movement in prices when markets are illiquid (i.e., market depth is lower). We estimate price impact by regressing log changes in price on one of two measures for net trading (*NT*) activity over a 5-minute interval:

$$\log(P_t) - \log(P_{t-1}) = \beta_0 + \beta_1 \times NT_t + \varepsilon_t. \quad (1)$$

Net trading activity is proxied by (i) the volume of buyer-initiated trades minus the volume of seller-initiated trades, and (ii) the number of buyer-initiated trades minus the number of seller-initiated trades over the 5-minute interval.

One drawback of the price-impact coefficient is that, although it necessitates the use of detailed high-frequency data, it is estimated over a longer sample period (weekly or yearly). The estimated price-impact coefficients therefore cannot be used directly in an analysis of intraday market conditions, unlike the five indicators discussed earlier. However, by analyzing the relationships between the five more traditional measures of liquidity discussed earlier and these more model-based ones, we may be able to gain some insight into the appropriateness of our high-frequency indicators.

3. The Government of Canada Securities Markets and the Role of Interdealer Brokers

The market for Government of Canada securities is the largest market in Canada, with $270 billion (par value) in bonds and $105 billion in treasury bills outstanding as of 31 March 2003. Like the government securities markets in most countries, the market for Government of Canada securities is primarily wholesale and institutional, where a small number of professional participants (typically, traders employed by securities dealers, pension funds, and mutual funds) conduct very large trades (often in excess of $25 or $50 million) on an infrequent basis. The market is currently divided into three segments: the primary market, the customer-dealer market, and the interdealer market.

In the primary market, the Bank of Canada conducts regular auctions of securities on behalf of the Department of Finance according to a pre-announced calendar. A group of dealers known as

government securities dealers (GSDs) are granted direct access to these auctions. A subset of the largest GSDs, known as primary dealers, have minimum bidding obligations at these auctions based on their level of activity and participation in the market. Institutional investors (i.e., "customers") may participate at these auctions by submitting their bids through one or more GSDs.

In the customer-dealer market, institutional investors typically trade with securities dealers on a bilateral, OTC basis over the telephone. The results of these bilateral customer-dealer trades are known only to the two counterparties, an opacity that is seen by participants as necessary to limit the price-impact costs of large trades.[4]

3.1 The interdealer market

Given the large and unpredictable inventory shocks typically faced by dealers in their trades with customers, interdealer debt markets have developed to facilitate inventory management and risk-sharing. Traditionally, interdealer trading has been conducted in a bilateral, telephone-based market, which is still typical in the customer-dealer market.

The introduction of IDBs has significantly reduced the role of bilateral interdealer trading in recent years. The current Canadian IDBs are screen-based voice brokers, which allow dealers to trade anonymously with each other. Each participant has a screen where bids, offers, and trade outcomes are posted. Participants post quotes and make trades by communicating with the broker over the telephone.

Based on dealer statistics reported to the Investment Dealers Association (IDA), the Canadian interdealer debt market represented approximately 46 per cent of the total secondary Government of Canada bond market trading volume in 2002, of which IDB trading accounted for 86 per cent (up from 50 per cent in 1991 and 75 per cent in 1997). This is comparable with the U.S. Treasury market, where the interdealer market accounted for 50 per cent of activity in 1997, of which trading on IDBs has been estimated to represent between 90 and 99 per cent (Gravelle 2002).

As stated earlier, an important feature of IDB trading is that, although a trade must occur at the last quoted price after the trade has been initiated, the size of the trade is subject to negotiation if both parties are willing. In addition, once other IDB participants become aware through the system that a trade has been initiated at a particular price, they may join in (on either side of the trade) after the trading needs of the original buyer or seller have been met. This is the "workup" process described in section 2.6; it continues until either total buying or selling interest with

4. More recently, electronic platforms have been introduced in Canada that offer simultaneous multiple-dealer quote inquiries and trading in one case, and peer-to-peer, order-driven trading in another.

respect to that trade has been satisfied. As Table 21 shows, order expansion beyond the initial quoted amount is far from uncommon. Table 21 also compares the average elapsed trading time, in seconds, for trades that have undergone size expansion and those that have not. For example, a trade in the 2-year benchmark without order expansion beyond the initial quoted amount requires an average of approximately 15 seconds (from the time that the initial quote is hit or lifted to the time that the final trade size is reported), whereas a trade that does undergo size expansion requires an average of 30 seconds.

4. Data and Sample Period

CanPX is a data service that consolidates and disseminates the trade and quotation data submitted by Canada's fixed-income IDBs. Introduced by Canada's IDBs and securities dealers to improve transparency in fixed-income markets, CanPX has been in operation since the summer of 2001, with the exception of the five and one-half month period immediately following 11 September 2001. Our sample covers the period from 25 February 2002 to 27 February 2003.

Each file from CanPX represents a record of the trade and quotation information presented on the screens of the four IDBs in the Canadian market over a portion or all of a given trading day.[5] Each line in the file is a "snapshot" of information that relates to a particular security at a precise moment in time: the price and/or yield of the best bid and offer (if any); the total amount offered and bid at each of the best inside quotes (across all of the IDB screens); the time at which the best bid and offer were last updated; whether a buyer-initiated or seller-initiated trade is currently being conducted; and, when a trade is completed, the trade outcome and the name of the IDB where the trade took place. The raw data set contains significant repetition and some data-entry errors which must be filtered prior to performing our analysis; the filtering methodology is described in Appendix A.

The CanPX data set is relatively complete in that it receives information from all of the Canadian IDBs (representing approximately 46 per cent of the total secondary Government of Canada bond market). By contrast, the U.S. Treasury market's GovPX system does not receive data from Cantor Fitzgerald, the IDB thought to be most active in the 30-year maturity sector. The CanPX data set, however, does not include information on the Canadian IDB "roll" markets, where dealers trade one security for another on a spread basis. Although this type of trading is thought to be more prevalent for treasury bills than for bonds, it represents a potentially significant amount of unseen trading activity in the interdealer bond market.

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5. Over our sample period, the four Canadian IDBs are Freedom International Brokerage Company, Prebon Yamane (Canada) Ltd., Shorcan Brokers Limited, and Tullett Liberty (Canada) Ltd.

In this study, we focus on benchmark Government of Canada bonds in the 2-, 5-, 10-, and 30-year sectors, the securities most actively quoted and traded on IDB markets. The benchmark for a given sector is the most recently issued security with a cumulative issue size over a certain threshold. The identity of the benchmark bond in each maturity sector changes periodically as old securities move out of the maturity sector and new securities are issued to take their places. As discussed in Appendix A, we follow convention in our identification of the benchmarks based on the Government of Canada's issuance calendar.

4.1 Constructing 5-minute-interval observations from continuous data

To construct the Kyle price-impact coefficient, and to facilitate examination of intraday variation in our other liquidity measures, each day is divided into 144 discrete 5-minute intervals (i.e., from 0600h to 1800h). The observation corresponding to each interval provides a "snapshot" of the most recently updated price and quotation information over the interval, and a record of cumulative trading and quotation activity over the previous five minutes with respect to that particular security. Where we attempt to characterize typical intraday patterns in the variables, an average across all of the days for each 5-minute interval is taken.

It is important to note that the filtered data set contains numerous 5-minute-interval observations (particularly at the beginning and end of the trading day) where either the last observation in the period is a one-sided quote, or the last observation reveals neither a firm ask nor bid. In those cases, no midpoint price is recorded for that interval. Where a midpoint price exists in both the current and previous intervals, intraday price changes are calculated by taking the difference of log 5-minute price observations.

5. Measuring Liquidity: Empirical Results

5.1 Liquidity indicators

5.1.1 Market activity: trading volume and trade frequency

Table 1 reports that average daily aggregate trading volume decreases with maturity for the 2-, 5-, 10-, and 30-year benchmark bonds, with the non-benchmarks lagging far behind. Among the benchmarks, there is a wide range from the highest to the lowest average trading volume.

Table 3 shows that the most frequently traded securities are (in descending order) the 10-, 2-, 5-, and 30-year benchmarks. Again, we find that trading activity is highly concentrated in the current benchmarks. The differences between sector benchmarks, however, are not as large as are found

with trading volume. This suggests that differences in typical trade size between the sectors can explain most of the variation in trading volume, and that the high degree of concentration in trading volumes in the short-dated benchmark bonds may overstate the apparent differences in activity levels. This observation of smaller typical trade sizes for longer-dated bonds makes sense, given the increased level of interest rate risk per dollar of face value associated with a position in a higher-duration security.

Both trading volume and trade frequency for the 2-year benchmark exhibit a clear intraday pattern (Charts 1 and 2), with most activity occurring in the morning between 8:30 and noon, slowing down over the lunch hour, and then picking up again modestly during the afternoon. The pattern is similar for the 5-, 10-, and 30-year benchmarks.

Daily observations of both trading volumes and trade frequency exhibit high standard deviations and are positively skewed, particularly for the non-benchmarks. Tables 2 and 4 show that trading activity is positively correlated across the benchmark bonds.

Corresponding with Karpoff's (1987) results, we find in Tables 22 to 25 that the weekly observations of average daily trading volume and trade frequency are positively correlated with the weekly standard deviation of 5-minute log returns. Similar to the findings of Huang, Cai, and Wang (2001) for the U.S. Treasury market, which show that volatility is more closely linked to trade frequency than trading volume, we observe that the trade frequency coefficients are higher than the corresponding coefficients calculated for the trading volume.[6]

5.1.2 Bid-ask spreads[7]

Table 5 reports descriptive statistics of average daily bid-ask spreads for the bonds. Note that the observed bid-ask spreads (in dollar terms) increase with maturity for the benchmark bonds.[8] In general, average daily bid-ask spreads appear to be relatively unskewed and stable across days compared with our two activity measures.

In Chart 3, average bid-ask spreads fall precipitously as the trading day begins, peak again twice around 8:30 (when most economic data are released) and 10, rise to a somewhat higher level near

6. Table 19 shows that volatility is positively correlated across benchmark bonds.
7. The interdealer bid-ask spreads examined in this paper should not be confused with the bid-ask spreads typically quoted to institutional investors in the bilateral customer-dealer market, which (according to anecdotal reports) tend to be narrower and more stable than those considered here.
8. Although we focus on interday and intraday variation in our indicators with respect to individual securities, an appropriate comparison of bid-ask spreads across sectors would require that they be expressed in yield terms (i.e., taking account of differences in duration). More generally, throughout this section, care should be taken in interpreting differences between the results for the maturity sectors as simple indications of relative liquidity, because such considerations have not been accounted for.

mid-day (the lunch hour), and then fall again to a somewhat lower level over the rest of the trading day.

Table 6 reports that bid-ask spreads are positively correlated across the benchmark bonds. As expected, we also find in Tables 22 to 25 that the average bid-ask spread is positively correlated with the daily standard deviations of 5-minute log returns (with the possible exception of the 10-year benchmark, where the coefficient is relatively small at 0.19).

5.1.3 Market depth: quote size, trade size, and the role of order expansion

Tables 7 and 9 show that the daily average quote and trade size, respectively, are largest for the 2-year benchmark and decrease with maturity for the benchmark bonds. Average daily quote size exhibits high standard deviations and is positively skewed, whereas deviations in average daily trade size are relatively small for the benchmarks compared with the other measures.

Although the average ask and bid quote sizes rise at the beginning of the trading day, Charts 4 and 5 do not seem to exhibit the pronounced intraday patterns that were observed for the three previous measures. The observed intraday pattern for average trade size (Chart 6) is more puzzling. Average trade size tends to be higher in the morning than in the afternoon, and it reaches its highest values very early in the morning, prior to 7:30. This may be due to the effect of a relatively small number of large trades in the early morning, which is typically very sparse in terms of trading activity, as Charts 1 and 2 show.

Tables 8 and 10 show that average quote and trade size, respectively, are positively correlated across the benchmark bonds, although the relationships appear to be relatively weak compared with the earlier measures (Tables 2, 4, and 6).

Note the large differences between average quote size and average trade size, which indicate that increasing the size of a trade subsequent to a quote being hit (i.e., the workup) has a significant impact on realized depth. Tables 15 and 17 show that, for the benchmarks, from 32 per cent to 45 per cent of trades undergo size expansion through the workup, and these trades account for from 64 per cent to 75 per cent of the total trading volume. These results suggest that quoted amounts significantly underestimate the amount of liquidity likely to be available at the quoted price. In addition, there does not appear to be a consistent pattern relating participants' use of order expansion to maturity sector, nor to benchmark/non-benchmark status. Tables 16 and 18 show that participants' use of order expansion is not strongly correlated across the benchmark bonds.

In Charts 7 and 8, we note that both the frequency of trades undergoing order expansion and the resulting trading volume exhibit intraday patterns that are similar to those observed for trading activity more broadly (Charts 1 and 2). Charts 9 and 10, however, show there is no clear intraday pattern in the proportional use of the order expansion protocol.

The observed degree of reliance on order expansion in the Canadian market is much larger than that observed by Boni and Leach (2002) for the U.S. Treasury market. For the on-the-run 5-year Treasury note, they find that 25.9 per cent of transactions undergo size expansion, and that these trades make up 45.6 per cent of total trading volume. For the Canadian market, the comparable figures are 41 per cent and 72 per cent, respectively.

Why would participants in the Canadian market utilize the workup to such a large degree compared with the U.S. market? Boni and Leach (2002) suggest that dealers use expandible orders to minimize the costs associated with asymmetric information. In particular, they find that dealers use the workup more often during relatively illiquid periods (outside of the New York trading day) and for relatively illiquid securities (non-benchmark securities). In this context, our finding of greater use of order expansion in the Canadian market is consistent with Canadian dealers making greater use of a strategy that may be particularly well-suited to a market where asymmetric information may be of greater concern. In contrast with Boni and Leach's (2002) results, however, we observe that order expansion is not more frequently observed for Canadian non-benchmarks than for benchmarks, which suggests that asymmetric information may not be the main explanation within the Canadian market.

5.1.4 Price-impact coefficients

Price-impact coefficients are the estimated coefficients from regressions of net trading activity on the log price changes at the 5-minute frequency. Tables 11 to 14 provide descriptive statistics of the price-impact coefficients estimated using the two measures of net trading activity: (i) the volume of buyer-initiated trades minus the volume of seller-initiated trades, and (ii) the number of buyer-initiated trades minus the number of seller-initiated trades over the 5-minute interval. While nearly all price-impact coefficient regressions yield estimates that are significantly different from zero, regressions in which the independent variable is the net number of trades have higher explanatory power than those where the independent variable is the net volume of trades. In Table 20, price-impact coefficients are estimated over the whole sample of 5-minute intervals. For the 2-year bond, the adjusted R-square is 0.0874 in the regression employing the net number of trades, whereas it is 0.0219 when net trading volume is substituted into the regression. In fact, for all benchmark bonds, net number of trades performs better that net trading volume. One possible

explanation for the large difference in explanatory power is the order expansion process that is integral to Government of Canada securities trading. Since any buyer and seller can join in to sell or buy a bond when a quote is "hit" or "taken" (at the agreed-upon price), the final reported trade volumes may no longer characterize just buyer- or seller-initiated trades.

For the magnitude of the price impact, we find on average a price increase of 0.0063 per cent for every net trade in the 2-year bonds, and a 0.0115, 0.0175, and 0.0196 per cent price increase for the 5-, 10-, and 30-year benchmark bonds, respectively (Table 11). On the other hand, every one million dollars of net trade in 2-year bonds induces a 0.0002 per cent price increase, compared with a price impact of 0.00065 per cent for 5-year, 0.0028 per cent for 10-year, and 0.0036 per cent for 30-year bonds (Table 13). We find that the average price impact of a trade for the 2-year benchmark is approximately four times the impact found by Fleming (2001). Results are similar when regressions are conducted over the whole sample period (Table 20). Both types of estimated price-impact coefficients increase with the duration of the bond.

5.2 Evaluating the measures: correlation results

An examination of the relationships between our measures is potentially useful in evaluating their appropriateness, because groups of measures that are consistently correlated with each other can be seen as useful proxies for each other. To the extent that some measures are more difficult to observe than others, the finding that a readily available one is correlated with other more sophisticated measures could have practical implications for market analysts. On the other hand, we might become skeptical regarding the appropriateness of a measure that is not consistently correlated with other measures, particularly if we have reason to believe *a priori* that some of those measures may be more appropriate on theoretical grounds. Tables 22 to 25 provide correlation coefficients for the four benchmark bonds.

Not surprisingly, trading volume and trade frequency are strongly correlated with each other for the four benchmarks. Trading volume can be considered a more appropriate indicator than trade frequency, since it is more strongly and consistently correlated with trade size and quote size. This may make sense because trading volume increases both with the number of trades (trade frequency) and trade size (an indicator of depth). Trade frequency, on the other hand, can be thought of as a "purer" measure of activity than trading volume, since it does not include the impact of realized trade depth. Finally, both trading volume and trade frequency are positively correlated with volatility, highlighting the potential ambiguity in the interpretation of heightened trading activity. In contrast with Fleming's (2001) results, both trading volume and trade frequency are negatively correlated with the bid-ask spread and the two price-impact coefficients

(with the exception of trade frequency in the 2-year sector), which suggests that these "activity" measures might be seen as useful (if perhaps somewhat ambiguous) indicators of liquidity in the Canadian IDB market.

As noted earlier, average quote size seems to underestimate the amount of liquidity available ex ante at the inside quotes, due to the common practice of order expansion through the "workup." Trade size may be a more suitable measure than quote size, since it directly reflects the amount of liquidity that was available at the quoted prices, ex post. Although trade size and quote size exhibit the expected sign of correlation with the bid-ask spread and the two price-impact coefficients, we observe that the relationships are relatively weak in some cases. Neither seems to be positively related to volatility.

Except for average trade size, our two proposed measures based on order expansion do not exhibit consistent correlations across the benchmark securities with respect to any of the activity or liquidity measures, nor with volatility. In addition to suggesting that these measures are inappropriate proxies for market liquidity, these results are in contrast to Boni and Leach's (2002) finding that order expansion strategies tend to be used by dealers under conditions of increased information asymmetry in the interdealer U.S. Treasury market.

The bid-ask spread and the two price-impact estimates consistently show the expected correlation with each other, as well as with volatility in almost all cases (i.e., except for the price-impact estimates for the 10-year benchmark). Given this result, combined with their model-derived and theoretic appeal as relatively direct measures of liquidity, we find that these indicators are the most appropriate of those considered in this study.

5.3 How liquid is the Canadian interdealer market?

Inoue (1999), using survey results from eleven countries, indicates that the Canadian debt market is relatively liquid in terms of its turnover ratio and its interdealer bid-ask spreads.[9] Having constructed a much broader series of measures for the Canadian interdealer bond market, what do our indicators tell us about its relative quality?

Table 26 compares the values of the liquidity measures for the 2-year benchmark with the results from a similar study by Fleming (2001) of the interdealer U.S. Treasury markets. While we have underscored the multifaceted (and therefore, in a sense, immeasurable) nature of market liquidity, and the importance of the differences between markets for interpreting liquidity measures, we can nonetheless attempt to make an intuitive comparison based on our results: In the brokered

9. Countries that participated in the survey include: Belgium, Canada, France, Germany, Italy, Japan, the Netherlands, Sweden, Switzerland, the United Kingdom, and the United States.

interdealer market for Government of Canada benchmark bonds, on average, trades of one-half the size are possible at quoted bid-ask spreads that are twice as wide, resulting in over two times the impact on prices, when compared with the U.S. Treasury market. In addition, the amount of market depth available ex ante seems to be less transparent in the Canadian market, due to the relative prevalence of order size expansion.

Given its position as the largest and arguably most liquid market in the world, this finding of a liquidity advantage for the U.S. Treasury market should not be surprising. However, the extent and nature of these differences along the various dimensions of liquidity may tell a more interesting story. Looking first at our activity measures, trading volume and trade frequency indicate approximately 20:1 and 11:1 differentials, respectively, favouring the United States for the 2-year benchmark. Given the large difference in the amount of securities issued in the two markets, turnover ratios (i.e., total trading volume divided by the stock of securities outstanding) may be more comparable; Inoue (1999) finds that the U.S. and Canadian turnover ratios are nearly identical, at 22 times and 21.9 times (putting them at third and fourth place, respectively, out of ten countries reporting).

We find that the average bid-ask spread for the Canadian 2-year benchmark is roughly twice that for the United States. Recall, however, that these measures are comparable only if the quoted amounts are equal. Since the average quote size is much smaller in Canada, the differential in bid-ask spreads between the two markets may overstate Canada's relative liquidity. Our estimate of the bid-ask spread for the Canadian 2-year benchmark corresponds very closely with Inoue's (1999) survey result, giving Canada the second smallest bid-ask spread out of eight countries reporting for that maturity sector.

The Canadian market's average trade size is roughly one-half, and its average quote size approximately one-eighth, that of the U.S. market. However, recall that quote size seems to underestimate true market depth at the inside quotes for the Canadian market, due to frequent use of the order expansion protocol. Trade size may therefore be a more comparable measure of actual or realized depth.

Our findings that Canada, compared with the United States, has relatively smaller quote sizes and a larger reliance on order size expansion indicate that the Canadian IDB market is one in which market conditions can be quite variable. In this market, dealers can compensate for concerns regarding information asymmetry by limiting the exposure of their trading intentions and timing their participation strategically to take advantage of intermittent price discovery.

6. Conclusions

In this paper, we have used a new high-frequency data set to construct a series of liquidity measures for the interdealer Government of Canada bond market, identifying intraday patterns and evaluating them in relation to each other and in comparison with the U.S. Treasury market. Our results suggest that bid-ask spreads and price-impact coefficients are the most appropriate indicators of those studied here, followed in approximate order by trade size, quote size, trading volume, trade frequency, and proposed measures based on participants' use of the order expansion protocol.

In contrast with Fleming's (2001) findings for the U.S. Treasury market, we find that price-impact coefficients and the bid-ask spread are typically negatively correlated with trading volume and trade frequency, which suggests that these latter (activity) measures may be seen as useful proxies for liquidity in the Canadian interdealer market. Given that the activity measures may be more easily observed than the other measures (i.e., they do not necessarily require high-frequency data), this finding may have implications for analysts and their surveillance of Canadian market conditions. The relationship between trading activity and price volatility may complicate the interpretation, however, particularly if we are interested in measuring liquidity during market crises or episodes of turbulence.

We find that Canadian dealers post relatively small quote sizes in relation to typical trade size, and make greater use of the order expansion protocol than dealers in the U.S. Treasury IDB market. Corresponding with Boni and Leach's (2002) findings, these observations are consistent with a market where participants attempt to hide their trading intentions to limit the costs associated with information leakage and stale quotes. We find, however, that order expansion is not more frequently observed for the less liquid securities, and furthermore that indicators of participants' use of the order expansion protocol are not consistently correlated with trading activity, liquidity, nor price volatility, which suggests that there is no simple link between concerns regarding information asymmetry and the prevalence of this important practice in the Canadian market.

A natural extension of this work is to investigate the determinants of changes in liquidity over time. D'Souza and Gaa (2003) explore the effect of macroeconomic announcements and Government of Canada securities auctions on market liquidity and price dynamics, and, in particular, the time-varying role of order expansion, which we find to be especially important to the Canadian market; D'Souza and Gaa employ an event study methodology to examine the conditions surrounding instances of significant limit order expansion.

Bibliography

Amihud, Y., H. Mendelson, and B. Lauterbach. 1997. "Market Microstructure and Securities Values: Evidence from the Tel Aviv Stock Exchange." *Journal of Financial Economics* 45: 365–90.

Andersen, T. 1996. "Return Volatility and Trading Volume: An Information Flow Interpretation of Stochastic Volatility." *Journal of Finance* 51: 169–204.

Boni, L. and C. Leach. 2002. "Expandable Limit Order Markets." University of New Mexico Anderson Schools of Management. Unpublished manuscript.

Brandt, M. and K. Kavajecz. 2003. "Price Discovery in the U.S. Treasury Market: The Impact of Orderflow and Liquidity on the Yield Curve." NBER Working Paper No. W9529.

Chordia, T., A. Sarkar, and A. Subrahmanyam. 2003. "An Empirical Analysis of Stock and Bond Market Liquidity." Federal Reserve Bank of New York Staff Report No. 164.

Clare, A., M. Johnson, J. Proudman, and V. Saporta. 1999. "The Impact of Macroeconomic News Announcements on the Market for Gilts." In *Market Liquidity: Research Findings and Selected Policy Implications*. Committee on the Global Financial System, The Bank for International Settlements, Basle, Switzerland.

Cohen, B. and H. Shin. 2003. "Positive Feedback Trading Under Stress: Evidence from the U.S. Treasury Securities Market." Bank for International Settlements Working Paper No. 122.

Committee on the Global Financial System (CFGS). 1999. "Market Liquidity: Research Findings and Selected Policy Implications." Bank for International Settlements.

Datar V., N. Naik, and R. Radcliffe. 1998. "Liquidity and Asset Returns: An Alternative Test?" *Journal of Financial Markets* 1: 203–19.

D'Souza, C. and C. Gaa. 2003. "Bond Market Liquidity, Order Expansion, and the Impact of Information." Bank of Canada. Unpublished manuscript.

Elton, E. and T. Green. 1998. "Tax and Liquidity in Pricing of Government Bonds." *Journal of Finance* 53: 1533–62.

Evans, M. and R. Lyons. 2002. "Order Flow and Exchange Rate Dynamics." *Journal of Political Economy* 110: 170–80.

Fleming, M. 1997. "The Round-the-Clock Market for U.S. Treasury Securities." *Federal Reserve Bank of New York Economic Policy Review* 3: 9–32.

———. 2001. "Measuring Treasury Market Liquidity." Federal Reserve Bank of New York Staff Report No. 133.

———. 2002. "Are Larger Treasury Issues More Liquid? Evidence from Bill Reopenings." *Journal of Money, Credit, and Banking* 34: 707–35.

Fleming, M. and E. Remolona. 1999. "Price Formation and Liquidity in the U.S. Treasury Market: Evidence from Intraday Patterns around Announcements." *Journal of Finance* 54: 1901–15.

Fleming, M. and A. Sarkar. 1999. "Liquidity in U.S. Treasury Spot and Futures Markets." In Committee on the Global Financial System report, *Market Liquidity: Research Findings and Selected Policy Implications.* Bank for International Settlements, May.

Furfine, C. and E. Remolona. 2001. "Price Discovery in a Market Under Stress: The U.S. Treasury Market in Autumn 1998." In *Financial Market Structure and Dynamics*, 97–101. Proceedings of a conference held by the Bank of Canada, November 2001. Ottawa: Bank of Canada.

Glosten, L. and L. Harris. 1988. "Estimating the Components of the Bid-Ask Spread." *Journal of Financial Economics* 21: 123–42.

Goldreich, D., B. Hanke, and P. Nath. 2003. "The Price of Future Liquidity: Time-Varying Liquidity in the U.S. Treasury Market." CEPR Discussion Paper No. 3900. London, Centre for Economic Policy Research.

Gravelle, T. 2002. "The Microstructure of Multiple-Dealer Equity and Government Securities Markets: How They Differ." Bank of Canada Working Paper No. 2002–9.

Gravelle, T. and R. Moessner. 2001. "Reactions of Canadian Interest Rates to Macroeconomic Announcements: Implications for Monetary Policy Transparency." Bank of Canada Working Paper No. 2001–5.

Green, T.C. 2003. "Economic News and the Impact of Trading on Bond Prices." Emory University. Unpublished manuscript.

Hamilton, J.D. 1994. *Time Series Analysis*. Princeton: Princeton University Press.

Hasbrouck, J. 1991. "The Summary Informativeness of Stock Trades: An Econometric Investigation." *Review of Financial Studies* 4: 571–91.

He, H. and J. Wang. 1995. "Differential Information and Dynamic Behavior of Stock Trading Volume." *Review of Financial Studies* 8: 919–72.

Huang, R., J. Cai, and X. Wang. 2001. "Inventory Risk-Sharing and Public Information-Based Trading in the Treasury Note Interdealer Broker Market." University of Notre Dame and City University of Hong Kong. Unpublished manuscript.

Inoue, H. 1999. "The Structure of Government Securities Markets in G10 Countries: Summary of Questionnaire Results." Bank of Japan. Unpublished manuscript.

Judge, G., R. Carter, W. Griffiths, H. Lutkepohl, and T. Lee. 1988. *Introduction to the Theory and Practice of Econometrics*. New York, NY: John Wiley and Sons.

Karpoff, J.M. 1987. "The Relation between Price Changes and Trading Volume: A Survey." *Journal of Financial and Quantitative Analysis* 22: 109–26.

Kyle, A. 1985. "Continuous Auctions and Insider Trading." *Econometrica* 53: 1315–35.

Madhavan, A. and S. Smidt. 1993. "An Analysis of Changes in Specialist Inventories and Quotations." *Journal of Finance* 48: 1595–1628.

Ng, K., R. Leng, and K. Phuah. 2001. "Impact of Credit Events on Treasury Securities Prices and Liquidity." National University of Singapore. Unpublished manuscript.

O'Hara, M. 1995. *Market Microstructure Theory*. Cambridge, MA: Blackwell Business.

Strebulaev, I. 2002. "Many Faces of Liquidity and Asset Pricing: Evidence from the U.S. Treasury Securities Market." London Business School. Unpublished manuscript.

Table 1: Daily Trading Volume ($ millions)

	Mean	Std. dev.	Median	75%	25%
Old 2Y benchmark	102.12	203.59	27.00	85.50	2.00
2Y benchmark	495.62	336.40	451.50	675.00	271.00
Old 5Y benchmark	45.95	74.00	11.00	50.00	0.00
5Y benchmark	285.32	175.24	256.25	378.00	167.70
Old 10Y benchmark	8.81	13.43	1.00	12.75	0.00
10Y benchmark	193.42	123.71	182.00	255.85	110.00
Old 30Y benchmark	6.88	10.67	3.70	9.00	0.00
30Y benchmark	92.77	60.29	77.00	120.00	51.00

Notes: Trading volume is the total of buyer- and seller-initiated trades each day between 0730h and 1700h over the period from 25 February 2002 to 27 February 2003. Benchmark Government of Canada bonds in the 2-, 5-, 10-, and 30-year sectors are the securities that are most actively quoted and traded on IDBs.

Table 2: Correlation Coefficients: Trading Volume

	2-year	5-year	10-year	30-year
2-year	1.00			
5-year	0.66	1.00		
10-year	0.73	0.55	1.00	
30-year	0.47	0.51	0.68	1.00

Note: Correlation coefficients are calculated using weekly observations of average daily trading volume over the period 25 February 2002 to 27 February 2003.

Table 3: Trade Frequency (trades per day)

	Mean	Std. dev.	Median	75%	25%
Old 2Y benchmark	7.32	15.06	3.00	6.00	1.00
2Y benchmark	41.67	23.58	40.00	54.00	26.00
Old 5Y benchmark	6.02	11.06	1.00	5.00	0.00
5Y benchmark	40.46	22.55	38.00	52.00	26.00
Old 10Y benchmark	1.38	1.86	1.00	2.00	0.00
10Y benchmark	42.17	24.02	40.00	55.00	28.00
Old 30Y benchmark	2.20	3.10	2.00	3.00	0.00
30Y benchmark	35.40	21.51	31.00	44.00	22.00

Note: Trade frequency is the total number of trades observed each day between 0730h and 1700h over the period from 25 February 2002 to 27 February 2003.

Table 4: Correlation Coefficients: Trade Frequency

	2-year	5-year	10-year	30-year
2-year	1.00			
5-year	0.72	1.00		
10-year	0.77	0.66	1.00	
30-year	0.54	0.66	0.68	1.00

Note: Correlation coefficients are calculated using weekly observations of the average number of trades per day for the period 25 February 2002 to 27 February 2003.

Table 5: Bid-Ask Spread (dollars per $100 face value)

	Mean	Std. dev.	Median	75%	25%
Old 2Y benchmark	0.02919	0.01690	0.02458	0.03200	0.01941
2Y benchmark	0.02120	0.00664	0.02018	0.02419	0.01719
Old 5Y benchmark	0.05678	0.03693	0.04672	0.06678	0.03636
5Y benchmark	0.04879	0.01496	0.04668	0.05396	0.04126
Old 10Y benchmark	0.07673	0.03143	0.07185	0.10000	0.05000
10Y benchmark	0.07593	0.02200	0.07267	0.08407	0.06426
Old 30Y benchmark	0.11195	0.06937	0.09872	0.12000	0.07120
30Y benchmark	0.10912	0.02248	0.10822	0.12128	0.09559

Note: Bid-ask spread is the average difference between the best bid and offer prices on each day between 0730h and 1700h over the period from 25 February 2002 to 27 February 2003 (see Appendix A).

Table 6: Correlation Coefficients: Bid-Ask Spread

	2-year	5-year	10-year	30-year
2-year	1.00			
5-year	0.57	1.00		
10-year	0.68	0.75	1.00	
30-year	0.62	0.69	0.66	1.00

Note: Correlation coefficients are calculated using weekly observations over the period 25 February 2002 to 27 February 2003.

Table 7: Quote Size ($ millions)—Ask & Bid

	Mean	Std. dev.	Median	75%	25%
Old 2Y benchmark	3.60	3.28	2.41	3.70	2.00
2Y benchmark	4.34	2.24	3.80	4.58	3.24
Old 5Y benchmark	2.80	1.52	2.09	3.14	1.94
5Y benchmark	3.73	1.37	3.42	4.37	2.68
Old 10Y benchmark	1.62	0.57	1.52	1.94	1.20
10Y benchmark	2.39	0.59	2.28	2.60	2.05
Old 30Y benchmark	1.92	2.02	1.18	1.66	1.00
30Y benchmark	1.43	0.34	1.33	1.52	1.21

Note: Quote size is the total amount dealers are willing to trade at the best bid and offer prices, on average, each day between 0730h and 1700h over the period from 25 February 2002 to 27 February 2003.

Table 8: Correlation Coefficients: Quote Size

	2-year	5-year	10-year	30-year
2-year	1.00			
5-year	0.41	1.00		
10-year	0.60	0.38	1.00	
30-year	0.24	0.30	0.30	1.00

Note: Correlation coefficients are calculated using weekly observations over the period 25 February 2002 to 27 February 2003.

Table 9: Trade Size ($ millions)

	Mean	Std. dev.	Median	75%	25%
Old 2Y benchmark	14.66	16.48	10.20	15.76	4.73
2Y benchmark	11.89	5.24	11.10	14.13	9.09
Old 5Y benchmark	10.10	9.59	6.07	11.56	4.15
5Y benchmark	7.11	2.42	6.70	8.30	5.50
Old 10Y benchmark	6.60	6.00	6.50	10.00	1.75
10Y benchmark	4.48	1.23	4.37	5.31	3.55
Old 30Y benchmark	3.30	2.66	2.00	4.94	1.46
30Y benchmark	2.64	0.87	2.50	3.05	2.04

Note: Trade size reflects the average amount that was actually traded at the bid or ask each day between 0730h and 1700h over the period from 25 February 2002 to 27 February 2003, and includes any order expansion that have may taken place once the initial quote was hit or lifted (the "workup").

Table 10: Correlation Coefficients: Trade Size

	2-year	5-year	10-year	30-year
2-year	1.00			
5-year	0.36	1.00		
10-year	0.53	0.40	1.00	
30-year	0.45	0.23	0.30	1.00

Note: Correlation coefficients are calculated using weekly observations over the period 25 February 2002 to 27 February 2003.

Table 11: Kyle (1)—Price impact of net number of trades

	Mean	Std. dev.	Median	75%	25%
2-year	0.0629	0.0239	0.0578	0.0724	0.0488
5-year	0.1145	0.0352	0.1090	0.1310	0.0948
10-year	0.1753	0.1273	0.1607	0.1865	0.1319
30-year	0.1957	0.0655	0.1975	0.2453	0.1507

Notes: Price-impact coefficients $\beta_1 \times 10^{-3}$ are estimated for each week by regressing log changes in price on the volume of buyer-initiated trades minus the volume of seller-initiated trades (NT) over each 5-minute interval between 0730h and 1700h. The mean coefficient is the average of the weekly estimates from the period 25 February 2002 to 27 February 2003. $\log(P_t) - \log(P_{t-1}) = \beta_0 + \beta_1 \times NT_t + \varepsilon_t$

Table 12: Correlation Coefficients: Kyle (1)—net number of trades

	2-year	5-year	10-year	30-year
2-year	1.00			
5-year	0.26	1.00		
10-year	0.31	-0.02	1.00	
30-year	0.26	0.17	0.04	1.00

Note: Correlation coefficients are calculated using weekly observations over the period 25 February 2002 to 27 February 2003.

Table 13: Kyle (2)—Price impact of net trading volume

	Mean	Std. dev.	Median	75%	25%
2-year	0.02044	0.01213	0.01812	0.02580	0.01316
5-year	0.06501	0.03755	0.06118	0.07375	0.04772
10-year	0.27699	0.39257	0.06025	0.66378	0.00000
30-year	0.35632	0.28709	0.30606	0.42586	0.17805

Notes: Price-impact coefficients $\beta_1 \times 10^{-4}$ are estimated for each week by regressing log changes in price on the volume of buyer-initiated trades minus the volume of seller-initiated trades (NT) over each 5-minute interval between 0730h and 1700h. The mean coefficient is the average of the weekly estimates from the period 25 February 2002 to 27 February 2003. $\log(P_t) - \log(P_{t-1}) = \beta_0 + \beta_1 \times NT_t + \varepsilon_t$

Table 14: Correlation Coefficients: Kyle (2)—net trading volume

	2-year	5-year	10-year	30-year
2-year	1.00			
5-year	-0.10	1.00		
10-year	0.16	-0.04	1.00	
30-year	0.09	0.03	-0.01	1.00

Note: Correlation coefficients are calculated using weekly observations over the period 25 February 2002 to 27 February 2003.

Table 15: Proportion of Trades with Order Expansion (the "workup")

	Mean	Std. dev.	Median	75%	25%
Old 2Y benchmark	0.41	0.14	0.38	0.50	0.33
2Y benchmark	0.45	0.05	0.45	0.47	0.41
Old 5Y benchmark	0.50	0.37	0.50	0.71	0.14
5Y benchmark	0.41	0.05	0.41	0.45	0.37
Old 10Y benchmark	0.32	0.40	0.06	0.56	0.00
10Y benchmark	0.34	0.06	0.35	0.38	0.32
Old 30Y benchmark	0.49	0.35	0.50	0.77	0.24
30Y benchmark	0.32	0.05	0.32	0.37	0.29

Notes: Proportion of trades with order expansion (calculated weekly) is the number of trades where final trade size is greater than the initial quoted amount divided by the total number of trades for that week. The sample is the interval between 0730h and 1700h over the period 25 February 2002 to 27 February 2003.

Table 16: Correlation Coefficients: Proportion of Trades with Order Expansion

	2-year	5-year	10-year	30-year
2-year	1.00			
5-year	0.17	1.00		
10-year	0.04	0.32	1.00	
30-year	0.22	0.45	0.23	1.00

Note: Correlation coefficients are calculated using weekly observations over the period 25 February 2002 to 27 February 2003.

Table 17: Proportion of Trading Volume for Trades with Order Expansion (the "workup")

	Mean	Std. dev.	Median	75%	25%
Old 2Y benchmark	0.67	0.24	0.76	0.86	0.53
2Y benchmark	0.75	0.06	0.75	0.79	0.71
Old 5Y benchmark	0.63	0.39	0.75	0.96	0.36
5Y benchmark	0.72	0.06	0.73	0.75	0.69
Old 10Y benchmark	0.44	0.46	0.26	0.99	0.00
10Y benchmark	0.65	0.09	0.68	0.71	0.63
Old 30Y benchmark	0.63	0.37	0.76	0.94	0.38
30Y benchmark	0.64	0.06	0.63	0.68	0.61

Notes: Proportion of trading volume with order expansion (calculated weekly) is the trading volume resulting from trades where final trade size is greater than the initial quoted amount divided by the total trading volume for that week. The sample is the interval between 0730h and 1700h over the period 25 February 2002 to 27 February 2003.

Table 18: Correlation Coefficients: Proportion of Trading Volume with Order Expansion

	2-year	5-year	10-year	30-year
2-year	1.00			
5-year	0.06	1.00		
10-year	0.11	0.04	1.00	
30-year	0.06	0.19	0.26	1.00

Note: Correlation coefficients are calculated using weekly observations over the period 25 February 2002 to 27 February 2003.

Table 19: Correlation Coefficients: Std. Dev. of Log Price Changes

	2-year	5-year	10-year	30-year
2-year	1.00			
5-year	0.73	1.00		
10-year	0.67	0.53	1.00	
30-year	0.74	0.67	0.72	1.00

Note: Daily standard deviation of logarithmic price changes over the period from 25 February 2002 to 27 February 2003.

Table 20: Kyle—Regressions (using all 5-minute observations in sample) for Benchmarks

	2Y	2Y	5Y	5Y	10Y	10Y	30Y	30Y
Constant	-0.4509e-06 (-0.4929)	-0.4957e-06 (-0.5259)	-3.5453e-06 (-2.3968)	-2.7502e-06 (-1.7918)	0.9168e-06 (0.4529)	0.9786e-06 (0.4597)	4.6896e-06 (1.5426)	1.7078e-06 (0.5453)
Net number of trades	0.6250e-04 (22.2182)		1.0496e-04 (28.1241)		1.5880e-04 (34.1994)		1.7638e-04 (22.4217)	
Net volume of trades		0.1625e-05 (8.2518)		0.5659e-05 (17.9478)		1.2425e-05 (14.660)		2.3142e-05 (9.2518)
Adjusted R-squared	0.0874	0.0219	0.0961	0.0333	0.1333	0.0414	0.0784	0.0221
DW	2.4783	2.4473	2.1898	2.1926	2.1630	2.1608	2.2258	2.2230
Observations	23738	23738	20906	20906	19514	19514	17208	17208

Notes: Price-impact coefficients β_1 are estimated over the period from 25 February 2002 to 27 February 2003 by regressing log changes in price on (i) the volume of buyer-initiated trades minus the volume of seller-initiated trades or (ii) the number of buyer-initiated trades minus the number of seller-initiated trades over each 5-minute interval. $\log(P_t) - \log(P_{t-1}) = \beta_0 + \beta_1 \times NT_t + \varepsilon_t$. *T*-statistics in parentheses are calculated using heteroscedastic-consistent (White) standard errors.

Table 21: Order Expansion ("the workup"): Summary Statistics

	Proportion of transactions with trade size > quoted depth	Proportion of trading volume of transactions with trade size > quoted depth	Average elapsed transaction time for trades with size <= quoted depth (in seconds)	Average elapsed transaction time for trades with size > quoted depth (in seconds)
2Y benchmark	0.4435	0.7535	14.9630	30.2966
Old 2Y benchmark	0.4183	0.7500	22.1151	41.3683
5Y benchmark	0.4048	0.7204	12.9760	26.1160
Old 5Y benchmark	0.3915	0.7080	12.4652	26.3378
10Y benchmark	0.3509	0.6713	12.7907	25.1229
Old 10Y benchmark	0.3934	0.7697	11.16	25.5833
30Y benchmark	0.3191	0.6386	11.7939	25.1480
Old 30Y benchmark	0.4466	0.7337	12.7719	26.5870

Notes: Once a trade has been initiated at a particular price, other dealers may join in (on either side of the trade) after the trading needs of the original buyer or seller have been met. The "workup" process continues until either total buying or selling interest with respect to that trade has been satisfied. Summary statistics are the sample means for all trades observed between 0730h and 1700h over the period from 25 February 2002 to 27 February 2003.

Table 22: Correlation Coefficients: 2-Year Benchmark

	Trading volume	Trade frequency	Bid-ask spread	Quote size	Trade Size	Kyle (1)	Kyle (2)	Workup (1)	Workup (2)	Std. dev.
Trading volume	1.00									
Trade frequency	0.92	1.00								
Bid-ask spread	-0.19	-0.08	1.00							
Quote size	0.08	0.01	-0.17	1.00						
Trade size	0.30	-0.08	-0.31	0.25	1.00					
Kyle (1)	-0.03	0.07	0.72	-0.15	-0.29	1.00				
Kyle (2)	-0.14	0.04	0.60	-0.25	-0.55	0.69	1.00			
Workup (1)	-0.02	-0.17	-0.27	0.02	0.37	-0.05	-0.06	1.00		
Workup (2)	-0.00	0.00	-0.11	-0.33	-0.04	0.09	0.01	0.55	1.00	
Std. dev.	0.30	0.50	0.54	-0.11	-0.38	0.60	0.42	-0.28	-0.03	1.00

Note: Correlation coefficients are calculated using weekly observations over the period 25 February 2002 to 27 February 2003.

Table 23: Correlation Coefficients: 5-Year Benchmark

	Trading volume	Trade frequency	Bid-ask spread	Quote size	Trade Size	Kyle (1)	Kyle (2)	Workup (1)	Workup (2)	Std. dev.
Trading volume	1.00									
Trade frequency	0.88	1.00								
Bid-ask spread	-0.17	-0.10	1.00							
Quote size	0.34	0.23	-0.23	1.00						
Trade size	0.40	-0.06	-0.22	0.40	1.00					
Kyle (1)	-0.38	-0.43	0.61	-0.38	-0.12	1.00				
Kyle (2)	-0.40	-0.41	0.40	-0.39	-0.22	0.76	1.00			
Workup (1)	0.19	-0.09	-0.04	-0.08	0.53	0.24	0.23	1.00		
Workup (2)	0.13	0.02	-0.15	-0.32	0.23	0.24	0.17	0.52	1.00	
Std. dev.	0.32	0.52	0.57	-0.00	-0.35	0.20	0.09	-0.19	-0.05	1.00

Note: Correlation coefficients are calculated using weekly observations over the period 25 February 2002 to 27 February 2003.

Table 24: Correlation Coefficients: 10-Year Benchmark

	Trading volume	Trade frequency	Bid-ask spread	Quote size	Trade Size	Kyle (1)	Kyle (2)	Workup (1)	Workup (2)	Std. dev.
Trading volume	1.00									
Trade frequency	0.94	1.00								
Bid-ask spread	-0.39	-0.36	1.00							
Quote size	0.24	0.10	-0.39	1.00						
Trade size	0.41	0.08	-0.25	0.45	1.00					
Kyle (1)	-0.27	-0.25	0.54	-0.25	-0.05	1.00				
Kyle (2)	-0.40	-0.37	0.55	-0.30	-0.15	0.96	1.00			
Workup (1)	0.41	0.27	-0.40	0.32	0.55	-0.36	-0.49	1.00		
Workup (2)	0.46	0.40	-0.45	0.13	0.36	-0.43	-0.55	0.85	1.00	
Std. dev.	0.53	0.58	0.19	-0.10	0.00	-0.16	-0.30	0.26	0.38	1.00

Note: Correlation coefficients are calculated using weekly observations over the period 25 February 2002 to 27 February 2003.

Table 25: Correlation Coefficients: 30-Year Benchmark

	Trading volume	Trade frequency	Bid-ask spread	Quote size	Trade Size	Kyle (1)	Kyle (2)	Workup (1)	Workup (2)	Std. dev.
Trading volume	1.00									
Trade frequency	0.91	1.00								
Bid-ask spread	-0.46	-0.31	1.00							
Quote size	0.04	-0.09	-0.38	1.00						
Trade size	0.22	-0.19	-0.39	0.33	1.00					
Kyle (1)	-0.28	-0.25	0.49	-0.22	-0.16	1.00				
Kyle (2)	-0.23	-0.09	0.39	-0.39	-0.42	0.68	1.00			
Workup (1)	0.08	-0.11	-0.01	-0.22	0.37	0.20	0.13	1.00		
Workup (2)	0.18	0.01	-0.04	-0.19	0.33	0.05	-0.08	0.82	1.00	
Std. dev.	0.22	0.40	0.38	-0.14	-0.47	0.17	0.29	-0.29	-0.13	1.00

Note: Correlation coefficients are calculated using weekly observations over the period 25 February 2002 to 27 February 2003.

Table 26: Liquidity in Canada and the U.S.: the 2-Year Benchmark

	Canada	U.S. (Fleming 2001)	Canada/U.S. (US$ = 1.5*Can$)
Trading volume	Can$0.496 billion	US$6.65 billion	0.05
Trade frequency	41.7 trades/day	467.2 trades/day	0.09
Bid-ask spread	Can$0.0212	US$0.007	2.02
Quote size	Can$4.34 million	US$24.5 million	0.12
Trade size	Can$11.89 million	US$14.2 million	0.56
Kyle (1) (net no. of trades)	Can$0.00625 per trade[a]	US$0.0016 per trade	2.60

a. Assuming a $100 face-value bond.

Chart 1: Average intraday trading volume in the 2–year benchmark ($ millions)

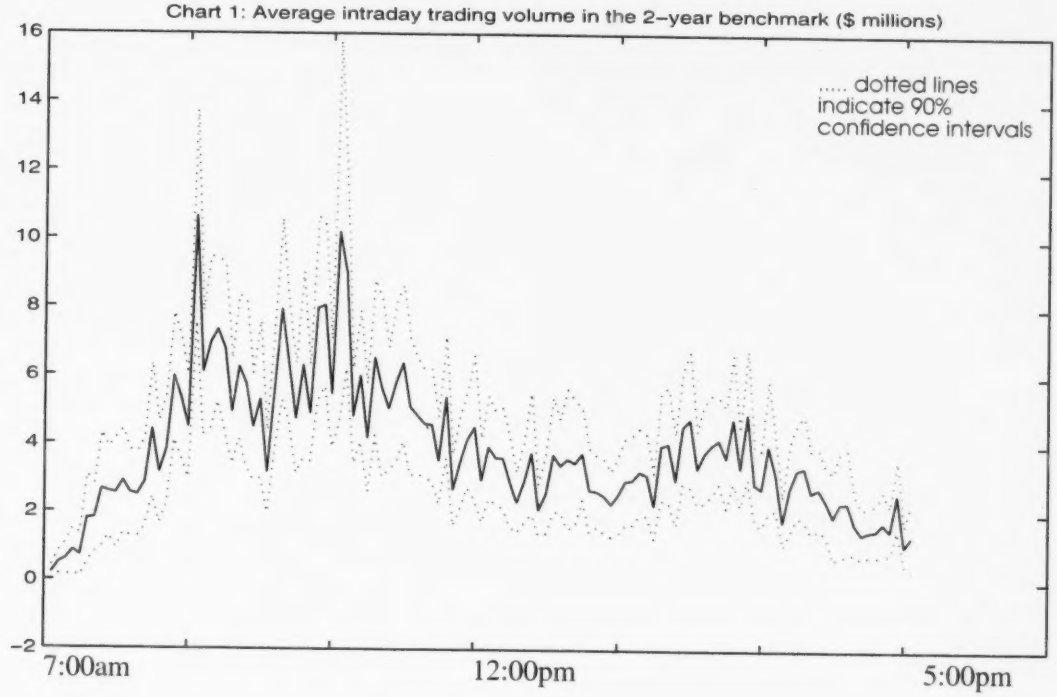


Chart 2: Average intraday trade frequency in the 2–year benchmark

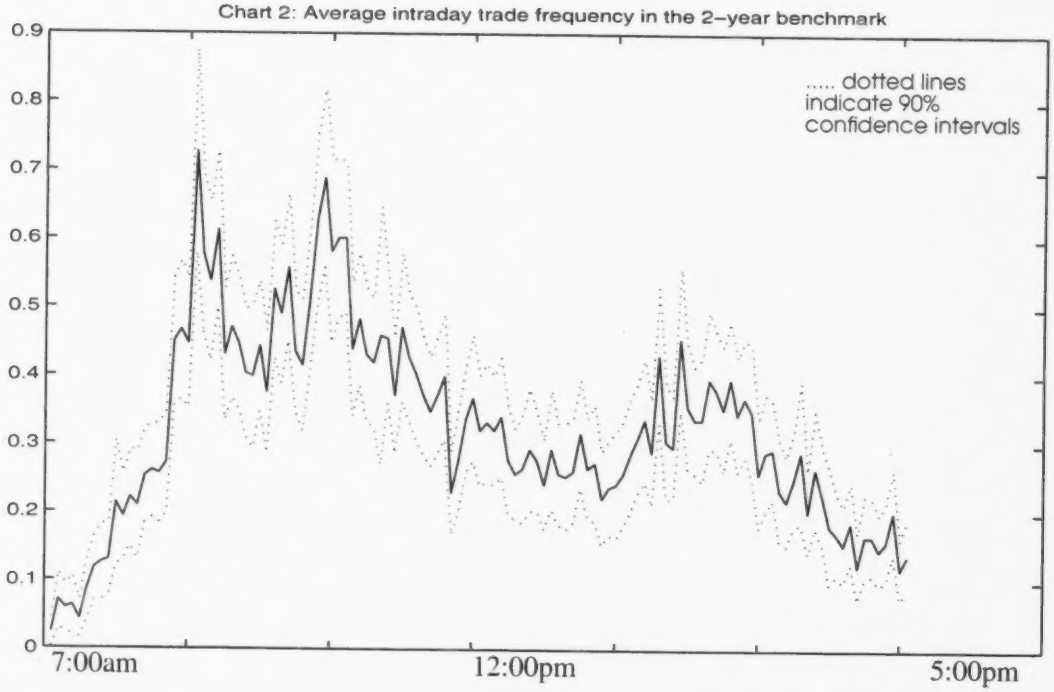


Chart 3: Average intraday bid–ask spread for the 2–year benchmark (dollars per $100 face value)

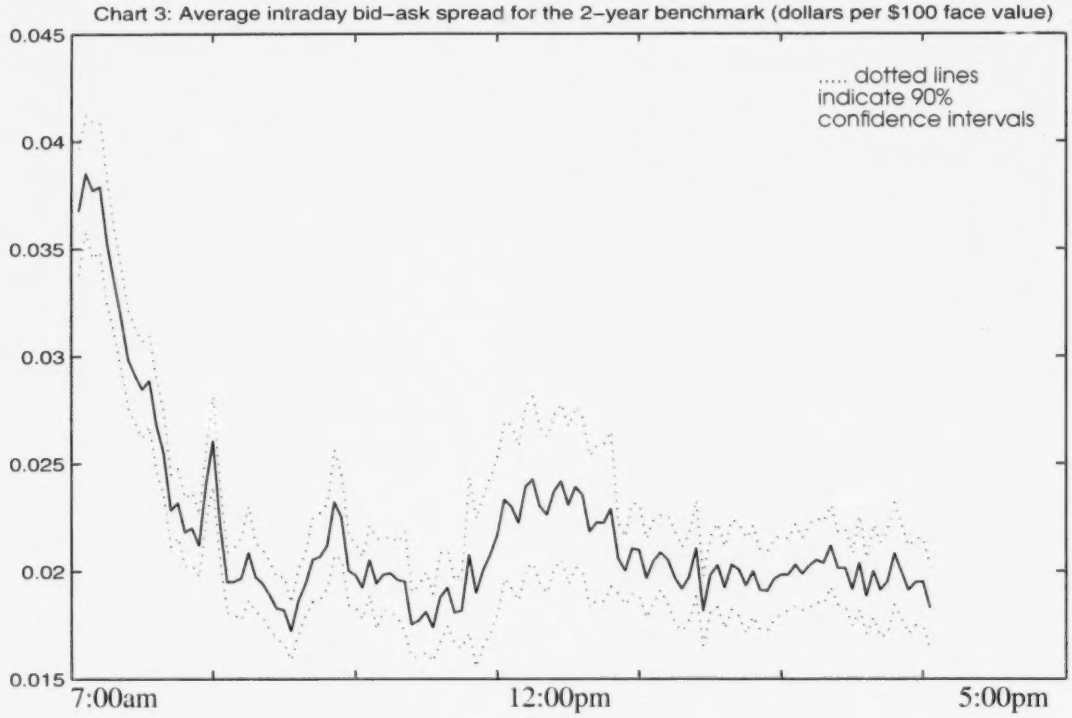


Chart 4: Average intraday ask quote size – 2–year benchmark ($ millions)

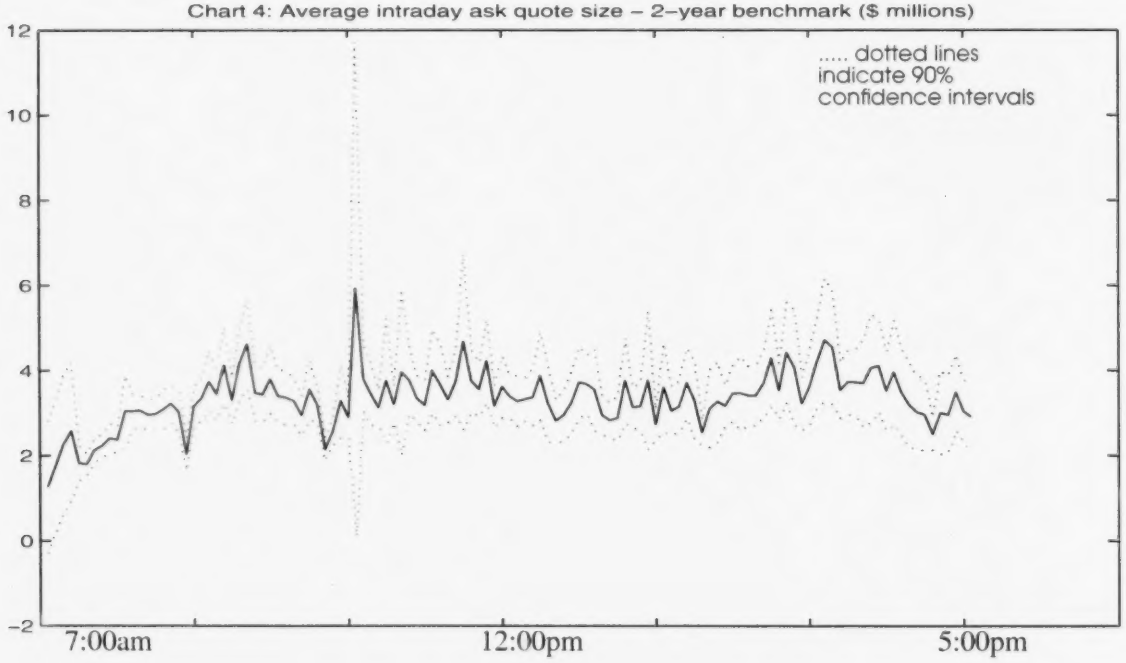


Chart 5: Average intraday bid quote size – 2–year benchmark ($ millions)

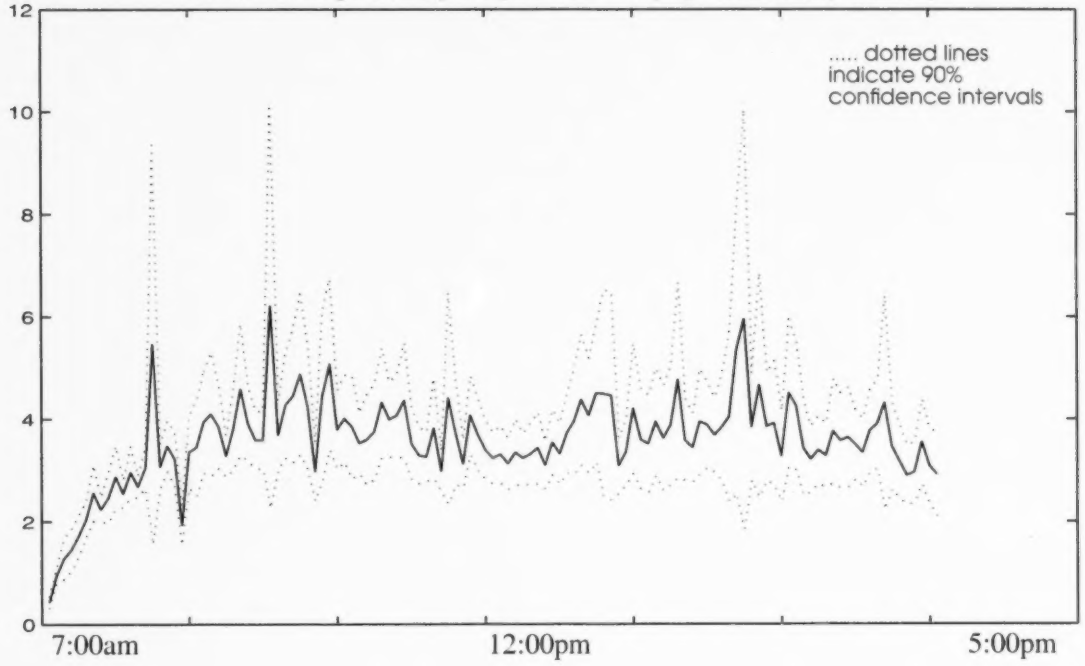


Chart 6: Average intraday trade size – 2–year benchmark ($ millions)

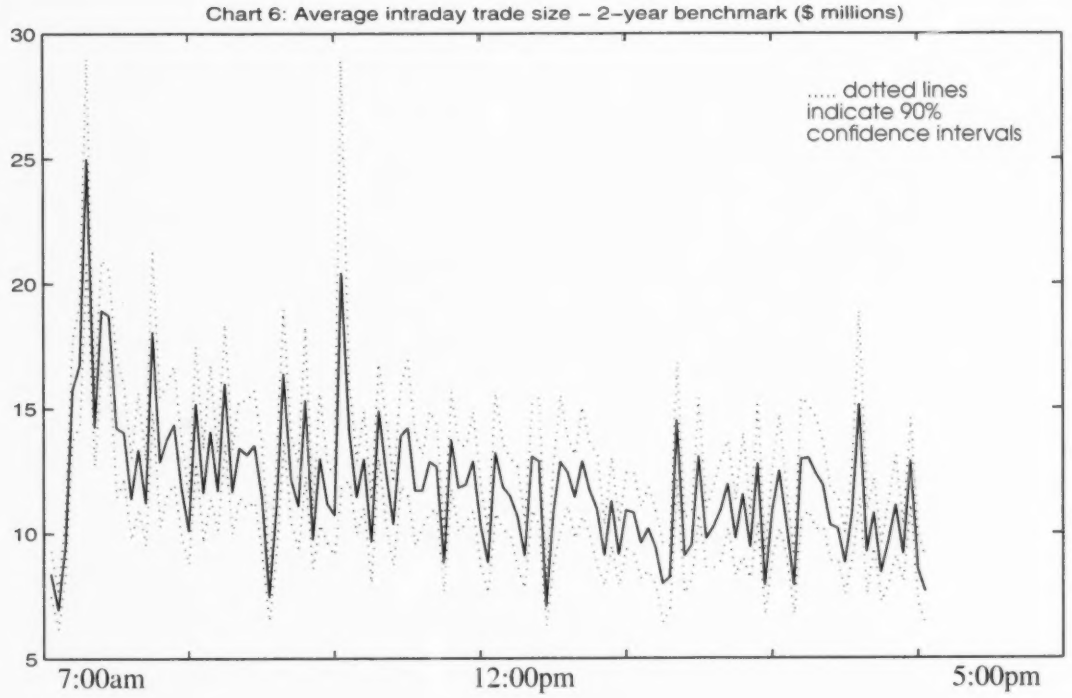


Chart 7: Average intraday trading volume of "worked up" trades – 2–year benchmark ($ millions)

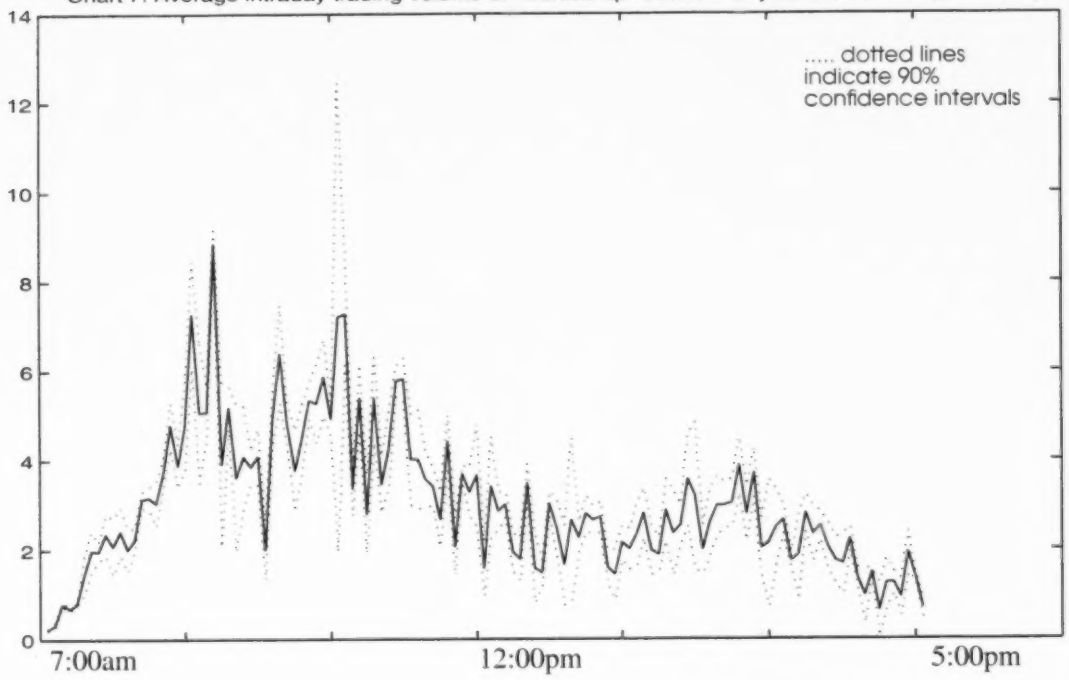


Chart 6: Average intraday trade size – 2–year benchmark ($ millions)

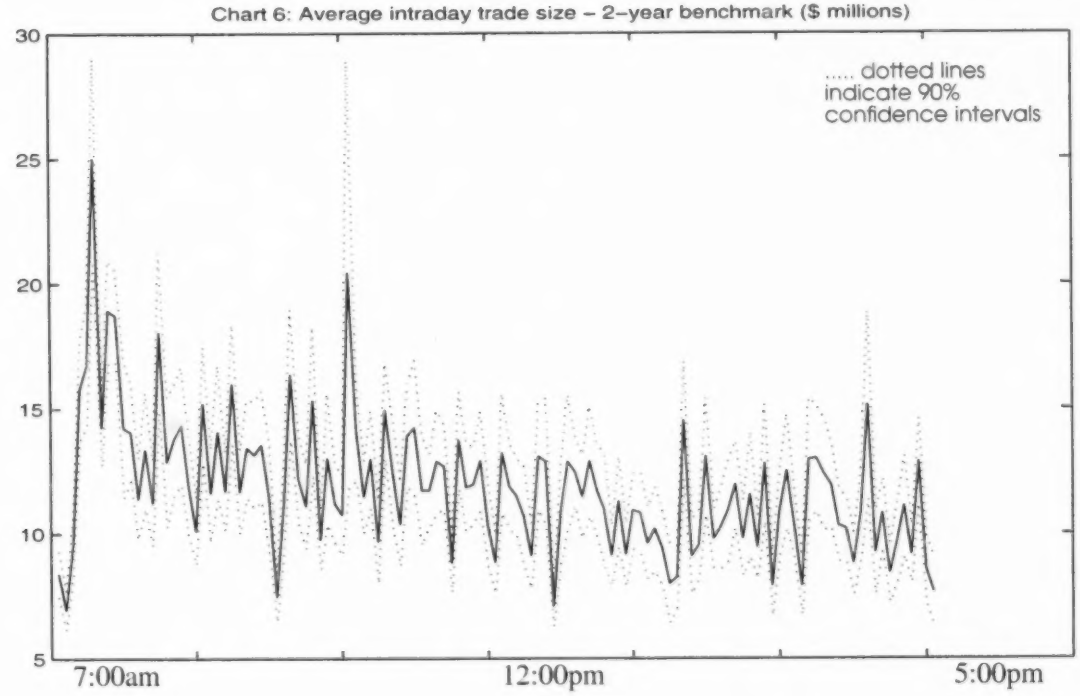


Chart 9: Proportion of trading volume from "worked up" trades – 2–year benchmark ($ millions)

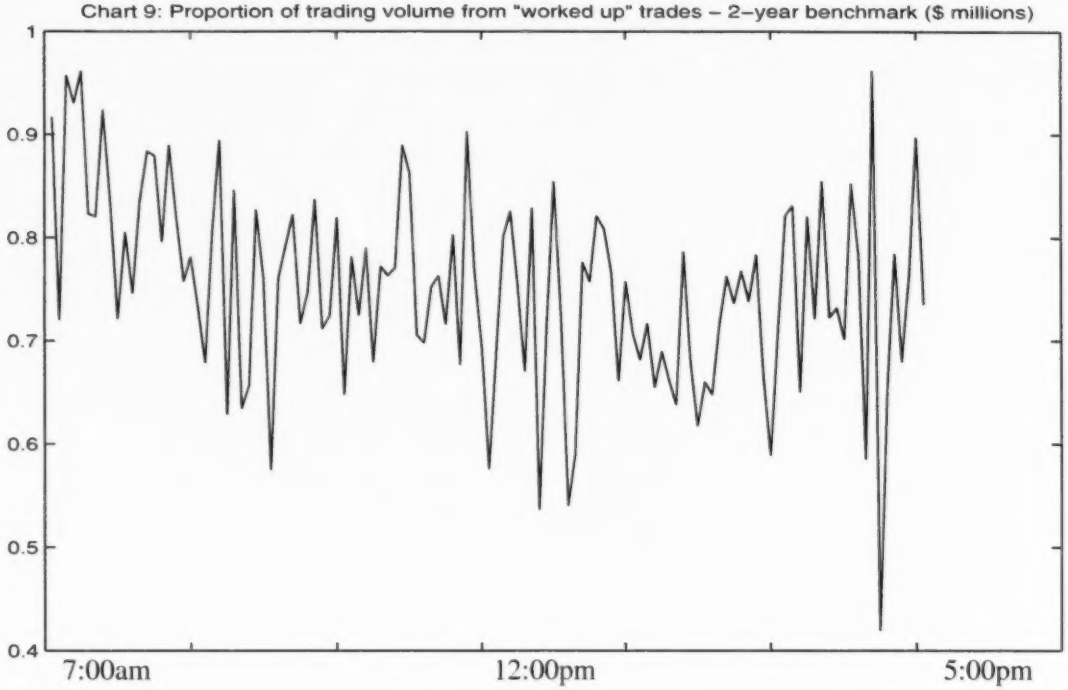
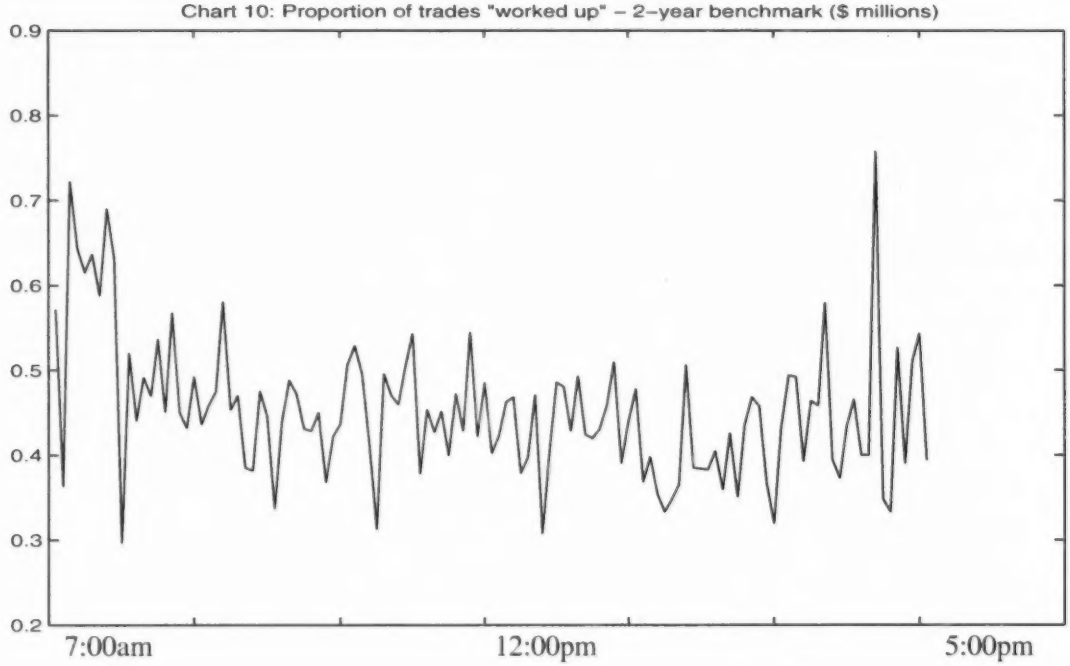


Chart 10: Proportion of trades "worked up" – 2–year benchmark ($ millions)



Appendix A: Filtering the Data

The raw data files from CanPX feature significant repetition, with identical lines of information appearing multiple times in some cases. In addition, there are user input errors that can significantly bias the results if not excluded. To deal with "bad quotes," our filtering process excludes two-sided quotes with a bid-ask spread of greater than 75 basis point (bps) or lesser than -10 bps, absolute 5-minute price changes larger than 0.9 per cent, and absolute 5-minute price changes that feature prices outside a plausible range.

The midpoint of the bid and ask quotes in a two-sided market is taken as the "market price." Although one-sided quote observations are retained to calculate average quote size (one of our liquidity measures), only observations that have two-sided quotes are considered with respect to prices.

A.1 Constructing the Benchmark Series

During our sample period, a switch in benchmarks occurs three times for the 2-year sector, twice for the 5-year sector, and once for the 10-year sector. It is necessary to create a rule for each sector that identifies the current and previous benchmark on each day. We follow convention by identifying a change in benchmark status based on the final auction at which that security's cumulative issuance crosses into the specified range of $7 to $10 billion for the 2-year sector, $9 to $12 billion for the 5-year sector, and $12 to $15 billion for the 10-year and 30-year sectors. For example, the 5-year benchmark was defined as 5.75 per cent September 2006 for the period of 25 February 2002 until the auction on 14 August 2002, at which time 4.5 per cent September 2007 was reopened for the fourth and final time, bringing cumulative issuance to $10.4 billion. On 14 August 2002, 4.5 per cent September 2007 became the current 5-year benchmark, while 5.75 per cent September 2006 was relegated to "old" benchmark status for the purposes of our dataset.

Although these benchmark transition points are consistent with the Government of Canada's debt issuance calendar, it is important to note that the market's perception of a change in benchmark status is actually a matter of consensus, rather than according to a strict rule. The result is that trading and quotation activity in the "new" benchmark may actually lag behind activity in the "old" benchmark for a period of days or weeks following the auction at which benchmark status "officially" changes, as market participants switch over to trading the new security. In those sectors where a new benchmark is created relatively infrequently (such as the 30-year sector), the current and previous benchmarks may share the stage in this way for a significant period of time.

A.2 Missing Data[1]

Whereas each of the IDBs that supply data to CanPX can feature quotes on a relatively large number of securities over the course of a trading day, the CanPX system displays consolidated information only with respect to a subset that consists of those considered to be most liquid. In general, CanPX displays information regarding two or three benchmark or near-benchmark securities in each of the maturity sectors. Unfortunately, although each sector's current identified benchmark is nearly always represented on CanPX, the identity of the second or third security shown in each sector can vary.

Immediately following a change in benchmark status, the second bond shown is typically the most recent benchmark. As time goes on, however, and the bond that will be the next benchmark is issued and grows in size, this prospective benchmark may take the place of the old benchmark alongside the current benchmark on the CanPX screen. Therefore, the "old benchmark" composite series in each sector may contain a number of missing days.

1. Missing days, 10-year benchmark only: 6 September 2002 to 4 October 2002.

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